Galactic SNR candidates in the ROSAT all-sky survey

Daniel Schaudel, Werner Becker and Wolfgand Voges

MPE, Giessenbachstrasse 1, 85740 Garching, Germany

Wolfgang Reich

MPIfR, auf dem Hügel 69, 43121 Bonn, Germany

Martin Weisskopf

MSFC, Space Sciences SD50, Huntsville, Alabama 35812, USA

Abstract. *Identified radio supernova remnants (SNRs) in the Galaxy comprise an incomplete sample of the SNR population due to various selection effects. ROSAT performed the first all-sky survey with an imaging X-ray telescope, and thus provides another window for finding SNRs and compact objects that may reside within them. Performing a search for extended X-ray sources in the ROSAT all-sky survey database about 350 objects were identified as SNR candidates in recent years (Busser 1998). Continuing this systematic search, we have reanalysed the ROSAT all-sky survey (RASS) data of these candidates and correlated the results with radio surveys like NVSS, ATNF, Molonglo and Effelsberg. A further correlation with SIMBAD and NED were used for subsequent identification purpose. About 50 of the 350 candidates turned out to be likely galaxies or clusters of galaxies. We found 14 RASS sources which are very promising SNR candidates and are currently subject of further follow-up studies. We will provide the details of the identification campaign and present first results.*

1. Introduction

Supernovae (SNe) are rare events, believed to occur at intervals of $\sim$30-50 years in the Galaxy (van den Berg & Tamman 1991; Tamman et al. 1994). However, in the past 2000 years, only 7 Galactic SNe have been observed — SN 185 (RCW86), SN 386 (G11.2-0.3), SN 1006, SN 1181 (3C58), Crab SN, Tycho SN, and Kepler SN. Most Galactic SNe appear unobserved owing to visible-band extinction by interstellar dust. When observational techniques in the radio band became available and the SNR Cas A was found to be the brightest radio source in the sky, several surveys and directed searches for SNR were performed at decimeter-wavelengths. Of course, radio observations are unhampered by interstellar dust. Currrently, about 250 SNRs have been identified in the radio band (Green 2000 and references therein). Although this catalog represents the result of more than 40 years of intensive search with the largest radio telescopes,

it is incomplete and strongly biased by mainly two selection effects: (i) the surface brightness of the remnant must be above the sensitivity limit of the observations, and (ii) the angular size of the remnant must be at least several times the resolution of the observations. These effects mean that not only are old faint remnants missing in the current catalogues, but there is also a deficit of young but distant SNRs (Green 1991). This is only a small fraction of SNRs of the total number expected according to the galactic SNe rate and the life-time of their remnants.

The RASS was performed from 1990 June to 1991 February and is the first (and only) all-sky survey done with an imaging X-ray telescope and thus provides another window that can be exploited to find SNRs as well as the compact objects that may reside within them. ROSAT was sensitive at soft X-ray energies (0.1-2.4 keV), had an angular resolution in survey mode of $\sim 96''$ and a limiting survey sensitivity of $f_x \sim 3 \times 10^{-13}$ erg cm^{-2} s^{-1} (Voges et al. 1999). The exposure time varied between about 400 s and 40,000 s in the ecliptic plane and poles respectively.

2.   Analysis and Results

Performing a search for extended ($\geq 5\ '$) and unidentified X-ray sources in the RASS database at $|b| \leq 15\ °$, about 350 objects were identified as potential SNR candidates (Busser 1998). Studying their X-ray morphology and correlating the results with radio catalogues and surveys like NVSS, ATNF, Molonglo and Effelsberg and the optical DSS as well as with SIMBAD and NED, allowed to discriminate between extragalactic background objects and SNR candidates, leaving 230 targets for subsequent identification purpose. About 50 of the 350 candidates turned out to be likely galaxies or clusters of galaxies, whereas ~ 70 were found to be spurious background features. So far, 14 RASS sources were found to be (very) promising SNR candidates and are currently subject of further follow-up studies in the X-ray and radio band. Due to the relatively low photon statistics and spatial resolution of the RASS data, it is not possible to perform a detailed analysis which allows to identify the nature of the objects. Below we briefly mention three targets which turn out to be likely SNRs according to their X-ray and radio morphology.

- G296.7-0.9 is located in a HII region (Russeil 1996) which is overlapping partly the area of radio emission. The target has an extent of about $15' \times 10'$ in X-rays and at radio wavelength. A pointed ROSAT HRI observation which has a 18 times higher angular resolution compared to the survey observation shows an incomplete shell in the east, supporting strongly the SNR interpretation (Fig. 1a/b).

- G308.3-1.4 is listed as a possible SNR in the MOST supernova remnant catalogue based on the composite radio morphology and the ratio of 60 μm to 843 MHz flux densities (Whiteoak 1992). The RASS PSPC data support this identification showing a hard X-ray source with a diameter of about $10'$ partly overlapping with the radio arcs (Fig. 1c).

- G38.7-1.4 shows (extended-doppelt) X-ray emission in the RASS with an extent of about $12' \times 8'$, surrounded by (a large radio arc) an incomplete

radio shell in the Effelsberg galactic plane 11 cm-survey (Reich et al 1990).
A follow-up observation with the Effelsberg 100-m telescope at 6 cm wave-
length was recently performed, which shows the shell to be significantly
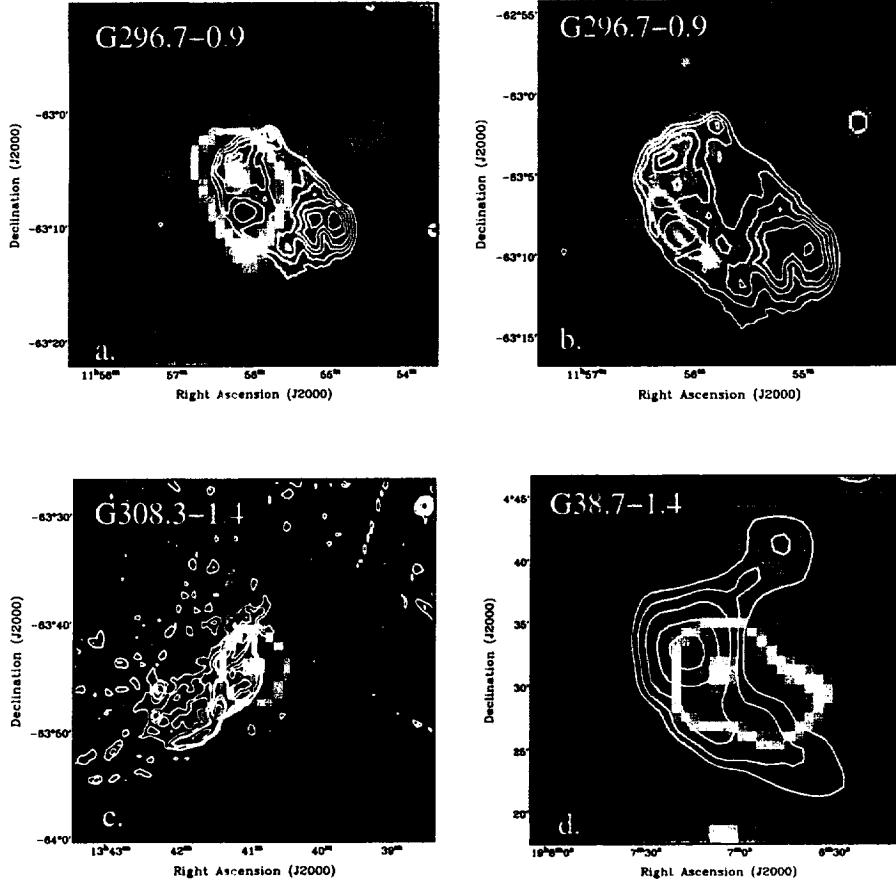polarized. This result clearly favours a SNR interpretation of G38.7-1.4
(Fig. 1d).

Fig. 1a. Greyscaled RASS image of G296.7-0.9 with superimposed radio contours the
MOST data at 843 MHz **b.** G296.7-0.9 as seen in the ROSAT HRI shown greyscaled.
The higher angular resolution resolves the extended X-ray source in a faint arc structure
located in the east **c.** RASS image of G308.3-1.4 overlaid with MOST data which show
an incomplete radio shell **d.** RASS image of G38.7-1.4 overlaid with contour lines from
the 11 cm Effelsberg survey

3.   Summary and Prospects

About 70 galactic SNRs are listed in Green's SNR Catalogue (Green 2000) be-
ing detected in X-rays. Making use of the spectro-imaging capability provided
by ROSAT in its all-sky survey, we reanalysed a sample of about 350 extended
X-ray sources, which were proposed by (Busser 1998) as SNR candidates. Per-
forming a more dedicated imaging analysis and making use of recently updated
databases like SIMBAD and the NED we reduced the number of SNR candidates
to be about 230. 14 of these targets turn out to be promising SNR candidates
based on availible data and are subject of follow-up observations for clarifica-
tion. Two candidates were recently observed with the Chandra observatory and
another six candidates with the Effelsberg 100-m telescope. The analysis of
these data is currently in progress. We will continue this campaign providing
additional observations in X-ray with XMM-Newton and Chandra and in radio
with Effelsberg and ATNF telescopes. Optical observations will complete our
multi-wavelength studies.

References

Busser, J.-U. 1998, PhD thesis, Munich

Green, D.A. 2000, 'A Catalogue of Galactic Supernova Remnants', Mullard
Radio Astronomy Observatory, Cambridge, United Kingdom

Green, D.A. 1991, PASP, 103, 209

Reich, W., Fürst, E., Reich, P., Reif, K. 1990, A&AS, 85, 633

Russeil, D. 1996, A&A, 319, 788

Tamman, G.A. 1994, The frequency of supernovae in Bludman, S.A., Mochkovitch,
R., Zinn-Justin, J., (eds.) Supernovae, Les Houches, 1990, p1

van den Berg & Tamman, G.A. 1991, ARA&A, 29, 363

Voges, W. et al. 1999, A&A, 349, 389

Whiteoak, J.B.Z. 1992, A&A, 262, 251